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U.S. Army Environmental Center

Uptake of Explosives from Contaminated Soil by Existing Vegetation at the Iowa Army Ammunition Plant

Report No. SFIM-AEC-ET-CR-95013

February 1995

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Prepared for:
U.S. Army Environmental Center
Environmental Technology Division
Program Management Branch
Safety Office
Aberdeen Proving Ground, Maryland

Prepared by:
Center for Environmental Restoration Systems
Energy Systems Division
Argonne National Laboratory
Argonne, Illinois

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February 1995

Submitted to:

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1995	Final, March 1994-Feb. 1995

4. TITLE AND SUBTITLE
Uptake of Explosives from Contaminated Soil by Existing Vegetation at the Iowa Army Ammunition Plant

5. FUNDING NUMBERS

6. AUTHOR(S)
J.F. Schneider, S.D. Zellmer, N.A. Tomczyk, J.R. Rastorfer, D. Chen, and W.L. Banwart

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Center for Environmental Restoration Systems
Energy Systems Division
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Environmental Center
Environmental Technology Division
Program Management Branch, Safety Office
Aberdeen Proving Ground, Maryland

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

SFIM-AEC-ET-CR-95013

11. SUPPLEMENTARY NOTES
P.O.C. William P. Houser (410) 612-6866

12a. DISTRIBUTION/AVAILABILITY STATEMENT

See DoDD 5230.24 "Distribution Statements on Technical Documents."

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

This study examines the uptake of explosives by existing vegetation growing in soils contaminated with 2,4,6-trinitrotoluene (TNT) and 1,3,5-trinitro-1,3,5-triazine (RDX) in three areas at the Iowa Army Ammunition Plant (IAAP). To determine explosives uptake under natural environmental conditions, existing plant materials and soil from the root zone were sampled at different locations in each area, and plant materials were separated by species. Standard methods were used to determine the concentrations of explosives, their derivatives, and metabolites in the soil samples. Plant materials were also analyzed. The compound TNT was not detected in the aboveground portion of plants, and vegetation growing on TNT-contaminated soils is not considered a health hazard. However, soil and plant roots may contain TNT degradation products that may be toxic; hence, their consumption is not advised. The compound RDX was found in the tops and roots of plants growing on RDX-contaminated soils at all surveyed sites. Although RDX is not a listed carcinogen, several of its potentially present degradation products are carcinogens. Therefore, the consumption of any plant tissues growing on RDX-contaminated sites should be considered a potential health hazard.

14. SUBJECT TERMS	15. NUMBER OF PAGES
TNT, RDX, Existing Vegetation, Uptake	viii + 24 = 32
	16. PRICE CODE

19. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	None

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Acknowledgments

The authors appreciate the assistance of Sandra Biedron and Wayne Triebold (summer students at ANL) in field collection of plant species for this study, as well as that of Judith Rastorfer and Paula Leach (of Chicago State University) in processing the voucher specimens. Financial support for this work was provided by the U.S. Army Environmental Center, Environmental Technology Division, Program Management Branch, Safety Office, Aberdeen Proving Ground, Maryland, through U.S. Department of Energy contract W-31-109-Eng-38.

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Abstract

This study examines the uptake of explosives by existing vegetation growing in soils contaminated with 2,4,6-trinitrotoluene (TNT) and 1,3,5-trinitro-1,3,5-triazine (RDX) in three areas at the Iowa Army Ammunition Plant (IAAP). To determine explosives uptake under natural environmental conditions, existing plant materials and soil from the root zone were sampled at different locations in each area, and plant materials were separated by species. Standard methods were used to determine the concentrations of explosives, their derivatives, and metabolites in the soil samples. Plant materials were also analyzed. The compound TNT was not detected in the aboveground portion of plants, and vegetation growing on TNT-contaminated soils is not considered a health hazard. However, soil and plant roots may contain TNT degradation products that may be toxic; hence, their consumption is not advised. The compound RDX was found in the tops and roots of plants growing on RDX-contaminated soils at all surveyed sites. Although RDX is not a listed carcinogen, several of its potentially present degradation products are carcinogens. Therefore, the consumption of any plant tissues growing on RDX-contaminated sites should be considered a potential health hazard.

1 Introduction

Researchers are concerned that plants growing on explosives-contaminated soil may take up contaminants and introduce them into the food chain. In a previous study at the Joliet Army Ammunition Plant (JAAP), Schneider et al. (1994) did not detect 2,4,6-trinitrotoluene (TNT) in the aboveground portions of plants growing on contaminated soil under natural environmental conditions. Under greenhouse conditions, however, Banwart et al. (1991) found that corn, soybeans, sorghum, and wheat took up 1,3,5-trinitro-1,3,5-triazine (RDX) from soils spiked with four levels of RDX. The results of this investigation showed that concentrations of RDX in plant materials increased as RDX levels in the soil increased. However, the potential for RDX to enter the food chain under field conditions via plants taking up the compound has not been documented.

In this study, we examined the uptake of TNT and RDX by existing vegetation growing on explosives-contaminated soils at the Iowa Army Ammunition Plant (IAAP). The IAAP is a government-owned, contractor-operated U.S. Army industrial facility encompassing 20,000 acres (Figure 1). The IAAP is adjacent to Middletown, Iowa, in Des Moines County, approximately 10 mi west of Burlington, Iowa, and the Mississippi River. Three areas contaminated with RDX, TNT, and other explosives-related contaminants at the IAAP were targeted for sampling: (1) the former Line 1 impoundment, (2) the Line 800 Pink Water Lagoon Area, and (3) the Explosives Disposal Area (EDA) burn pads.

1.1 Former Line 1 Impoundment Area

The Line 1 facilities (Figure 2) are located in the northeastern portion of the installation. During the period 1948–1975, the Army reported that Line 1 generated the greatest volume of explosives waste and pink water at IAAP. In 1948, a dam was constructed along the upper reaches of Brush Creek to impound effluent discharged from Line 1. This impoundment extended about 1,300 ft upstream of the dam and covered approximately 3.6 acres. The primary function of the impoundment appears to have been to allow the particulates from explosives-contaminated wastewater to settle before it was discharged downstream. Other wastes included minor amounts of coal from a nearby coal pile and condensate from a coal-fired power plant. In 1957, the dam and some of the accumulated sediments were removed and impounding was discontinued.

Plant specimens representing this area were collected from two different types of soils — the Colo soils and Gara-Rinda complex soils. The first type of soil on which plants were sampled is mapped as Colo silty clay loam with 0–5% slopes (number 133B, Brown 1983). These soils are poorly drained and moderately permeable on floodplains, on alluvial fans, and along upland drainage ways. The Colo soils developed in silty alluvium with native prairie grasses. *Phalaris arundinacea* (4019/110) came from a dense floodplain stand adjacent to Brush Creek, where it was abundant; its common associates were *Polygonum punctatum* (4020) and *Pilea pumila* (4021). *Asclepias syriaca* (4023/112-1), *Solidago canadensis* var. *hargeri* (4024/112-2), and *Helianthus nuttallii* (4025/122-3) were collected from a floodplain stand a short distance west of Brush Creek, in which *S. canadensis* var. *hargeri* was the most abundant species. *Juniperus virginiana* (4026/113) was collected at the western edge of the Brush Creek floodplain. It most likely occurred in a transition soil between the Colo and Gara-Rinda soils.

The second type of soil on which plants were sampled is mapped as Gara-Rinda complex with 9–14% slopes, indicating moderate erosion (loam-silt loam; number 893D2, Brown 1983). The soils of this complex occur on convex side slopes and in coves at the head of drainage ways in uplands. The Gara soils are well or moderately well drained and moderately slowly permeable on lower slopes, whereas the Rinda soils are poorly or somewhat poorly drained and very slowly permeable on upper slopes. The two soils usually occur, however, in small areas and are so highly intermixed that separate mapping is impractical. Gara soils developed in glacial till with mixed native grasses and deciduous trees, and the Rinda soils developed in clayey weathered glacial till with mixed grasses and deciduous trees. *Robinia pseudo-acacia* (4007/20 and

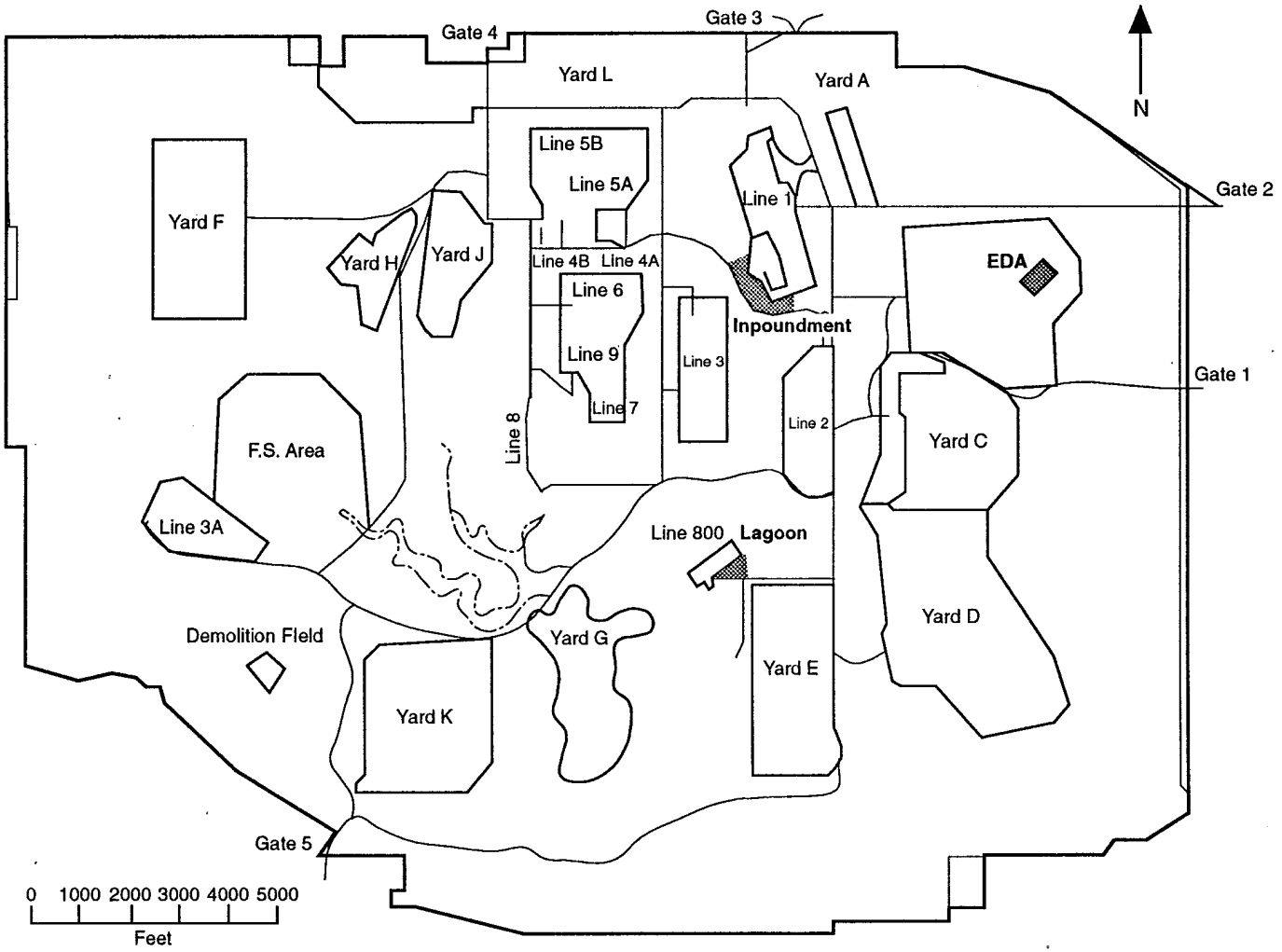

FIGURE 1 Iowa Army Ammunition Plant

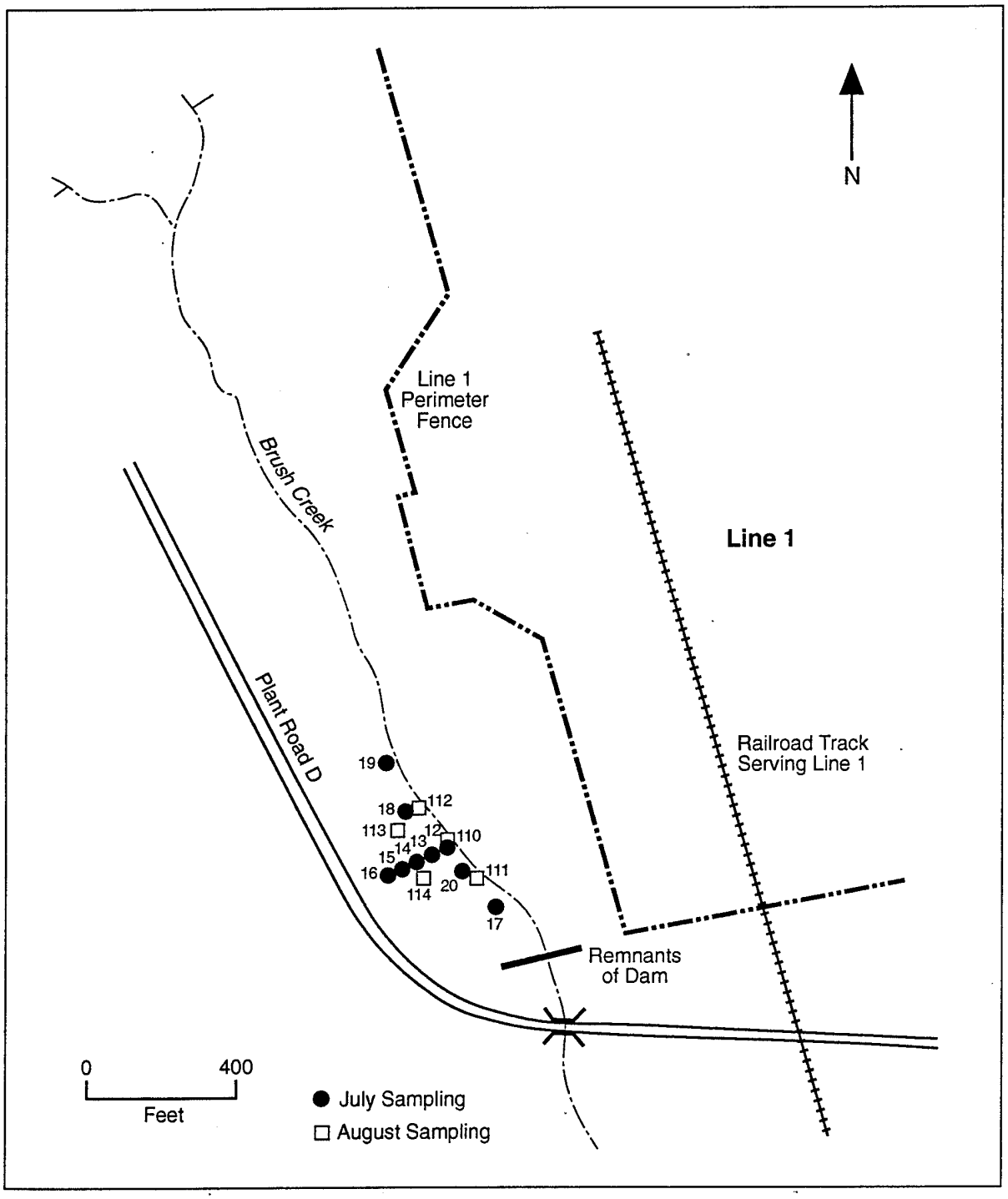

FIGURE 2 Former Line 1 Impoundment Area

4022/111) was collected from a stand on the slope above the west floodplain of Brush Creek. Specimens of a different *R. pseudo-acacia* (4028/114-2) tree were collected in a stand of a shallow depression a few yards west of the slope. Also, *S. canadensis* (4027/114-1) was collected from the understory of this stand, in which it was a common understory component.

1.2 Line 800 Pink Water Lagoon Area

The Line 800 Pink Water Lagoon Area is adjacent to Line 800 and an intermittent tributary to Brush Creek (Figure 3). It consists of an unlined, 5-ac impoundment approximately 4 ft deep at capacity, surrounded by an earthen berm. From 1943 to 1955, the primary activity at Line 800 was ammunition renovation. The Line 800 Pink Water Lagoon Area was constructed in

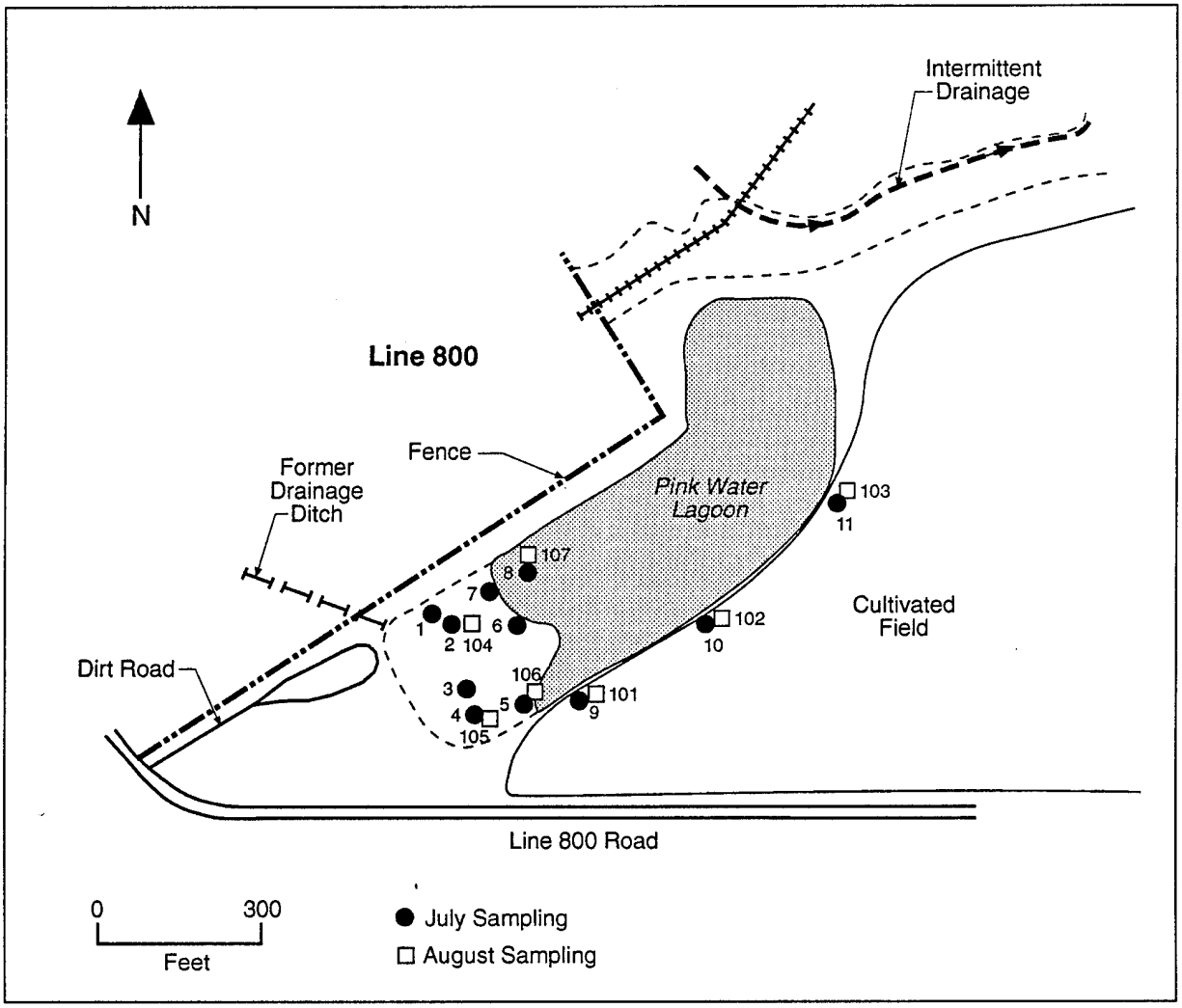

FIGURE 3 Line 800 Pink Water Lagoon Area

1943 for the disposal of effluent from Line 800 and sludges trucked in from other operations around IAAP. The primary waste disposed of at this site is assumed to be explosives-contaminated wastewater.

The soil of the Pink Water Lagoon Area is mapped as Taintor silty loam with 0–1% slopes (number 279, Brown 1983). Taintor soils are poorly drained and moderately slowly permeable in upland ridge tops. These soils developed in loess with native prairie grasses. The spontaneous vegetation of the area consisted of a mosaic of small plant communities from essentially pure stands of forbs or grasses to mixed stands of a few herbaceous plants. *Ambrosia artemisiifolia* (4016/107), *Bromus inermis* (4002/4, 4012/105), *Polygonum* sp. (4001/2), and *P. pensylvanicum* (4011/104) were collected from relatively pure stands, whereas *Amaranthus* sp. (4003/5A), *A. palmeri* (4013/106), and *Echinochloa crusgalli* (4004/5B) were collected from a mixed stand associated with *Eragrostis pectinacea* (4014) and a few scattered plants of *A. artemisiifolia.* Healthy plants of *Sagittaria calycina* (4005/8) were collected during a July 12–13, 1994, field trip when the soil was wet, but only dead, depauperate remains of the species were seen during an August 23–24, 1994, field trip because the soil was dry and hard. Although all of the plants of this area showed low moisture stress during the August 23–24 field trip, apparently only members of the *S. calycina* population expired as a result of the drought at that time.

1.3 Explosives Disposal Area (EDA) Burn Pads

The EDA eastern burn pads are located in the northeast corner of IAAP, approximately a mile from the installation's boundary. The EDA consists of eight raised earthen burn pads enclosed in a fenced area of approximately 12 acres. Activities at the EDA included open burning of explosives-contaminated metals, propellant explosives, and pyrotechnic materials. The pads were in operation until 1982.

The soil of the Explosives Disposal Area is mapped as Givin silt loam with 1–3% slopes (number 75, Brown 1983). The Givin soils are somewhat poorly drained and moderately slowly permeable on ridge tops and slopes at the head of drainage ways in uplands. These soils developed in loess with a mixture of native prairie grasses and deciduous trees. Human activities altered the landscape, resulting in a mosaic of knolls. Specimens of *A. artemisiifolia* (4017/108), *Solidago* sp. (4006/14), and *S. canadensis* (4018/109) were collected from an interknoll area where they were common.

2 Experimental Procedure

Samples of soil and plant material were collected in the three study areas at IAAP. Field screening was performed by using D TECH on-site test kits for RDX, according to the U.S. Environmental Protection Agency's (EPA's) SW 846 Method 4051. Field screening allowed us to select sampling locations containing RDX contamination. Only locations with positive results for RDX were selected for plant sampling. Sample locations are indicated in Figures 2–4.

At each sampling location, the aboveground portions (shoots) of each selected plant species were clipped about 1 in. above the soil surface. Care was taken to prevent the shoots from coming into contact with the soil. Roots were collected separately from the shoots. To promote air drying and prevent molding and decomposition, the fresh shoots and roots of each plant species were placed in separate paper bags and labeled. Soil was collected from the 0–6 in. depth of the root zone by using a 1-in. soil probe. Soil samples were placed in precleaned bottles, and U.S. Army Environmental Center (USAEC) guidelines were followed for sample collection and handling.

Voucher specimens were collected concurrently with the plants collected for chemical analyses. These specimens were placed in a plant drying press within an hour of collection. For herbaceous taxa, whole plants were collected; for woody taxa, twigs with attached leaves were collected.

After adequate drying, the voucher specimens were studied to confirm field identifications; McGregor et al. (1986) was used as the floristic reference. Appendix A lists the taxa making up the collection — common names, family names, and other information are also provided. In addition, the voucher specimens were mounted on standard herbarium sheets and are being housed in an herbarium cabinet at Argonne National Laboratory (ANL); duplicate specimens, if available, are housed at Chicago State University (CSU) in the ANL/CSU Cooperative Herbarium.

2.1 Procedure for Soil Analysis

The EPA's SW-846 method 8330 was used to determine concentrations of explosives and their derivatives in soil at each sampling location. This method involves extracting 1 g of air-dried soil by using sonication with acetonitrile. After extraction, the sample is analyzed by using high-performance liquid chromatography (HPLC) with ultraviolet detection. This method is effective in detecting TNT, RDX, 1,3,5-trinitrobenzene (TNB), 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), 4-amino-2,6-dinitrotoluene (4A-DNT), and 2-amino-4,6-dinitrotoluene (2A-DNT). A Beckman System Gold HPLC was used with a Beckman Ultrasphere C-18 (25 cm × 4.6 mm, 5 μm) analytical column. The mobile phase was 58/42 (methanol/water).

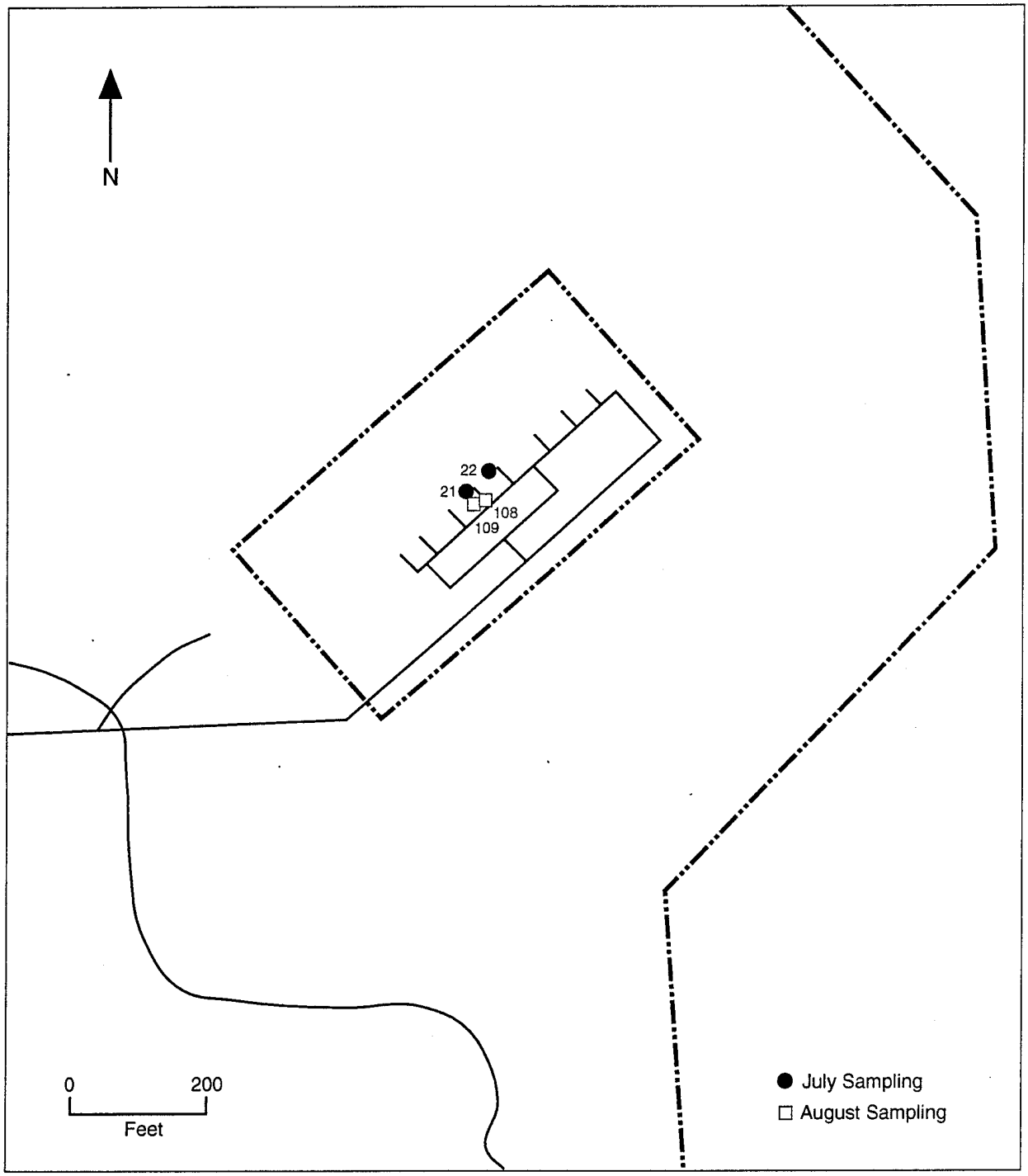

FIGURE 4 Explosives Disposal Area

2.2 Procedure for Plant Analysis

A method developed by Banwart and Hassett (1990) was used to analyze plant materials for explosives uptake. In this method, plant material is washed with distilled water to remove any explosives clinging to the surface. By washing the plant material, one can differentiate (1) explosives taken up into the plant from explosives in the soil from (2) those on the plant's surface. For TNT determination, 0.5 g of plant material is dried and extracted with dichloromethane. Extracts are run through a Florisil column to remove interfering compounds. The samples are analyzed by using HPLC with ultraviolet detection. To determine RDX in plant materials, dried plant material (0.2 g) is extracted with 1 N HCl. Then, 2.0 mL of HCl extract is pipetted into a glass vial and mixed with 2.0 mL of acetonitrile. The solution is filtered through a 0.2-μm filter, and the sample is analyzed by means of HPLC with ultraviolet detection. Compounds targeted by these methods include RDX, TNT, 1,3,5-TNB, 2,4-DNT, 2,6-DNT, 4A-DNT, and 2A-DNT. In this study, a Beckman System Gold HPLC was used with a Supelco LC-CN (25 cm × 4.6 mm, 5 μm) analytical column. The mobile phase was 17/13/70 (methanol/tetrahydrofuran/water).

Soil and plant analyses were performed in a USAEC-certified laboratory at the University of Illinois at Urbana. Spiked samples were run to check the validity of the procedure. On plant tops, spike recovery averaged 89% for TNT, 80% for RDX, 60% for 4A-DNT, and 90% for 2A-DNT. For roots, spike recovery averaged 66% for TNT, 80% for RDX, 48% for 4A-DNT, and 84% for 2A-DNT.

3 Results and Conclusions

Tables 1 and 2 contain the analytical results of samples collected at IAAP. At most sampling locations in all three areas, TNT and RDX were found at concentrations above their detection limits in the soil. Only TNT and RDX concentrations in soil and plant tissues are reported in Tables 1 and 2. Appendix B contains a list of all analytical results.

3.1 TNT Uptake

Some soil samples containing TNT also had lower concentrations of TNB, 2,4-DNT, 4A-DNT, and 2A-DNT. Two of the 35 plant shoot samples from IAAP had detectable concentrations of TNT; however, no TNT degradation products were detected in these samples. TNT was not detected in a second foliage sample collected in August from the same black locust (*Robinia pseudo-acacia*) tree (Locations 20 and 111 on Figure 2). Smooth brome shoots were collected at IAAP and also at the Joliet Army Ammunition Plant (JAAP), but TNT was not detected in these samples. These findings suggest that possible sample contamination or TNT uptake is related to the stage of growth in some plant species. Detectable concentrations of 4A-DNT (10.7 mg kg^{-1}) and 2A-DNT (4.5 mg kg^{-1}) were found in only one plant shoot, common ragweed, collected from the lagoon area during July, but the TNT concentration was below the detection limit in this sample. Common ragweed was collected again at the lagoon and EDA areas during August, but these degradation products were not detected in the samples. These findings suggest that 4A-DNT and 2A-DNT were associated with soil not removed during sample washing. Corn was sampled from three locations on the edge of the field adjacent to the lagoon area. During July, only leaves were collected, but in August, separate collections of leaf, stalk, grain, and root were made. No TNT or any TNT degradation products were detected in any of the corn samples. Also, the concentrations of TNT in all root samples collected at IAAP were below the limits of detection, but 4A-DNT and 2A-DNT were detected in several root samples. Also, the compounds 4A-DNT and 2A-DNT were found in several root samples collected at JAAP, but these samples usually contained detectable levels of TNT.

According to material published by the National Institute for Occupational Safety and Health (NIOSH), the lowest dose of TNT lethal to a human is 28 mg kg^{-1} of body weight. In a report of munitions literature compiled by Sriharan (1992), the toxicity of 4A-DNT and 2A-DNT varies by animal test species. A daily average of 25 mg kg^{-1} resulted in symptoms ranging from anemia to death within 22 days. Although mice did not show signs of absorbing the compounds, larger rodents and primates did. Some animal species partially or fully recovered after treatment ceased, while others had permanent damage, such as sterility. Low concentrations of TNT were found in the two plant tops at IAAP. Low concentrations of TNT, 4A-DNT, and 2A-DNT were also present in plant roots at both JAAP and IAAP. Because these compounds were found at low concentrations, a human would need to consume a large amount of plant material containing these compounds at the observed concentrations to suffer toxic effects. For example, a 68-kg person would need to ingest 430 kg of the black locust foliage with 4.4 mg kg^{-1} of TNT to equal the lowest published lethal dose of TNT for a human. This 68-kg person would need to consume

TABLE 1 Results of Samples Collected July 12–13, 1994

Location[b]	Plant		Contamination in Sampled Component (mg kg^{-1}[a])					
			Soil		Plant Shoot		Plant Root or Wood	
	Common Name	Botanical Name	TNT	RDX	TNT	RDX	TNT	RDX
1[c]			48	<1				
2	Smartweed	*Polygonum* sp.	3,610	2.5	<0.5	51.2	<0.5	<1
3			5.6	<1	<0.5			
4	Smooth Bromegrass	*Bromus inermis*	42,700	5,010	<0.5	<1	<0.5	<1
5	Pigweed	*Amaranthus* sp.	526	59.7	<0.5	3.6	<0.5	<1
6	Pigweed	*Amaranthus* sp.	47.6	6.5	<0.5	<1	<0.5	<1
7			6.3	<1				
8	Arrowhead	*Sagittaria calycina*	10,500	1,160	<0.5	<1	<0.5	7.4
9	Corn	*Zea mays*	9.9	1.4	<0.5	<1		
10	Corn	*Zea mays*	4.2	<1	<0.5	<1		
11	Corn	*Zea mays*	1.1	<1	<0.5	<1		
12	Reed Canary Grass	*Phalaris arundinacea*	4.5	19.4	<0.5	10.1		
13			1.6	<1				
14	Goldenrod	*Solidago* sp.	<0.5	<1	<0.5	<1	<0.5	263
15			<0.5	<1				
16			0.6	<1				
17	Reed Canary Grass	*Phalaris arundinacea*	1.8	1.4	<0.5	<1		
18	Goldenrod	*Solidago* sp.	5.1	57.1	<0.5	35	<0.5	904
19-1	Reed Canary Grass	*Phalaris arundinacea*	0.9	9	<0.5	<1		
19-2	Goldenrod	*Solidago* sp.	0.9	9	<0.5	23.6		
20	Black Locust	*Robinia pseudo-acacia*	13.8	114	4.4	38.6	<0.5	<1
21	Common Ragweed	*Ambrosia artemisiifolia*	15,900	702	<0.5	73.9	<0.5	31.5
22			43	174				

[a] ppm.

[b] Locations 1–11 = Pink Water Lagoon Area. Locations 12–20 = Former Impoundment Area. Locations 21–22 = Explosives Disposal Area.

[c] Plant samples were taken only at locations where RDX contamination was found.

TABLE 2 Results of Samples Collected August 23–24, 1994

Location[b]	Plant		Contamination in Sampled Component (mg kg^{-1}[a])							
			Soil		Plant Shoot		Plant Root or Wood		Grain	
	Common Name	Botanical Name	TNT	RDX	TNT	RDX	TNT	RDX	TNT	RDX
101	Corn	*Zea mays*	26.5	<1	<0.5	<1	<0.5	<1	<0.5	<1
102	Corn	*Zea mays*	5.5	<1	<0.5	<1	<0.5	<1	<0.5	<1
103	Corn	*Zea mays*	2.3	<1	<0.5	<1	<0.5	<1	<0.5	<1
104	Pennsylvania Smartweed	*Polygonum pensylvanicum*	32.2	3.2	<0.5	5.03	<0.5	4.09		
105	Smooth Bromegrass	*Bromus inermis*	11,000	1,800	0.76	41.5	<0.5	15.8		
106	Palmer's Pigweed	*Amaranthus palmeri*	22.6	3.8	<0.5	10.7	<0.5	20.2		
107	Common Ragweed	*Ambrosia artemisiilfolia*	143	3.7	<0.5	<1	<0.5	<1		
108	Common Ragweed	*Ambrosia artemisiilfolia*	4,660	166	<0.5	33.4	<0.5	17.7		
109	Canada Goldenrod	*Solidago canadensis*	33,700	1,100	<0.5	37.9	<0.5	2.3		
110	Reed Canary Grass	*Phalaris arundinacea*	15.9	43.3	<0.5	<1	<0.5	<1		
111	Black Locust	*Robinia pseudo-acacia*	7.6	16	<0.5	17.2	<0.5	5.77		
112-1	Common Milkweed	*Asclepias syriaca*	2.7	46.1	<0.5	88.6	<0.5	8.2		
112-2	Canada Goldenrod	*Solidago canadensis*			<0.5	5.64	<0.5	<1		
112-3	Tall Sunflower	*Helianthus nuttallii*			<0.5	8.61	<0.5	4.28		
113	Red Cedar	*Juniperus virginiana*	4.7	16.8	<0.5	42				
114-1	Canada Goldenrod	*Solidago canadensis*	0.8	<1	<0.5	<1				
114-2	Black Locust	*Robinia pseudo-acacia*			<0.5	<1				

[a] ppm.

[b] Locations 101–107 = Pink Water Lagoon Area. Locations 108–109 = Explosives Disposal Area. Locations 110–114 = Former Impoundment Area.

daily about 158 kg of ragweed tops with 10.7 mg kg^{-1} of 4A-DNT to produce symptoms. At these levels of consumption, the threat of TNT, 4A-DNT, and 2A-DNT to human health by plant uptake is very low.

3.2 RDX Uptake

During July and August, RDX was detected in both plant shoot and root samples from all areas at IAAP. Plants sampled represented a range of species with different duration and life forms, and RDX was detected in representatives of each group. Two tree species were sampled, black locust *(R. pseudo-acacia)* and red cedar *(Juniperus virginiana)*. The compound RDX was detected in the foliage of the black locust and red cedar and in the wood of black locust trunks. Therefore, the potential exists for RDX to enter the food chain via fruit- and nut-bearing trees. Although RDX was detected in the soil at one location in the corn field (Location 9) during July, no RDX was found in the corn leaf tissue. Locations in the corn field were sampled again in August, but no RDX was detected in any soil or corn leaf, stalk, grain, or root samples. Comparison of RDX concentrations in the soil with those in plant shoots or roots suggests no apparent direct relationship. At some locations with high RDX concentrations in soil, plant tissues contained little or no RDX, while at other locations with low RDX concentrations in soil, plant tissues contained RDX concentrations higher than those found in the soil.

At the one location during the July collection (Location 14) where RDX was not detected in the soil, the root of goldenrod (*Solidago* sp.) contained 263 mg kg^{-1} RDX. Generally, if RDX was detected in plant roots, it was also detected in the plant shoots. In a number of plants, there was a higher concentration of RDX in the plant shoots than in the roots. This finding indicates both RDX uptake and differential accumulation in different plant organs. Results from other investigations (Cataldo et al. 1993; Banwart 1991, unpublished data) indicate RDX uptake and accumulation in different plant tissues is species-dependent. The limited number of samples from individual species collected during this study prevents the development of species or plant organ vs. RDX relationships.

The compound RDX is not listed as a carcinogen, and the Occupational Safety and Health Administration has not established a Permissible Exposure Limit. According to data published by NIOSH, the lowest lethal dose for RDX to rodents ranges from 10 to 500 mg kg^{-1} d^{-1}. Effects of RDX on humans (other than contact effects with dust) are not known, but some RDX degradation products are suspected to be toxic. One of the compounds in the anaerobic pathway discussed by McCormick et. al. (1981) is dimethylnitrosamine, which is considered a potent carcinogen and is listed as such by the EPA. Although the concentrations of RDX in plants sampled at IAAP were low, the possible presence of potential carcinogenic degradation products indicates there may be a human health hazard.

3.3 Summary

Results from this study indicate that TNT and its degradation products are not translocated to plant tops in existing vegetation or crops growing on explosives-contaminated soils. The compounds TNT, 4A-DNT, and 2A-DNT were sometimes found associated with plant root samples growing in TNT-contaminated soils. Because TNT, 4A-DNT, and 2A-DNT were not detected in aboveground portions of plants, vegetation growing on TNT-contaminated soils is not considered a health hazard. Nevertheless, soil and plant roots may contain TNT degradation products that may be toxic, and their consumption is therefore not advised. In contrast, RDX was found in the shoots and roots of plants growing on RDX-contaminated soils at all sites surveyed at IAAP. Although RDX is not a listed carcinogen, several of its potentially present degradation products are carcinogens. For this reason, the consumption of any plant tissues growing on RDX-contaminated sites may be considered a potential health hazard. The potential of RDX contamination affecting human health via the food chain (plant-animal-human) is not known at this time.

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Appendix A:

Voucher Specimen Collection

TABLE A.1 List of Vascular Plant Voucher Specimens from Iowa Army Ammunition Plant, Des Moines County, Iowa

CI#[a]	SI#[b]	Latin Name	Common Name	Family	MBBS[c]	Area[d]
July 12-13, 1994, Collection						
4001	2	*Polygonum* sp.	Smartweed	Polygonaceae	220	PWL
4002	4	*Bromus inermis*	Smooth Bromegrass	Poaceae	1144	PWL
4003	5A	*Amaranthus* sp.	Pigweed	Amaranthaceae	180	PWL
4004	NA	*Echinochloa muricata*[e]	Barnyard Grass	Poaceae	1165	PWL
4005	8	*Sagittaria calycina*[f]	Arrowhead	Alismataceae	1026	PWL
4006	14	*Solidago* sp.	Goldenrod	Asteraceae	1000	IMP
4007	20	*Robinia pseudo-acacia*	Black Locust	Fabaceae	477	IMP
4008	NA	*Robinia pseudo-acacia*[g]	Black Locust	Fabaceae	477	IMP
4009	NA	*Robinia pseudo-acacia*[g]	Black Locust	Fabaceae	477	IMP
4010	21	*Ambrosia artemisiifolia*	Common Ragweed	Asteraceae	856	EXD
August 23-24, 1994, Collection						
4011	104	*Polygonum pensylvanicum*	Penn. Smartweed	Polygonaceae	227	PWL
4012	105	*Bromus inermis*	Smooth Bromegrass	Poaceae	1144	PWL
4013	106	*Amaranthus palmeri*	Palmer's Lovegrass	Amaranthaceae	182	PWL
4014	NA	*Eragrostis pectinacea*	Carolina Lovegrass	Poaceae	1176	PWL
4015	NA	*Echinochloa muricata*[e]	Barnyard Grass	Poaceae	1165	PWL
4016	107	*Ambrosia artemisiifolia*	Common Ragweed	Asteraceae	856	PWL
4017	108	*Ambrosia artemisiifolia*	Common Ragweed	Asteraceae	856	EXD
4018	109	*Solidago canadensis*	Canada Goldenrod	Asteraceae	1002	EXD
4019	110	*Phalaris arundinacea*	Reed Canary Grass	Poaceae	1207	IMP
4020	NA	*Polygonum punctatum*	Water Smartweed	Polygonaceae	227	IMP
4021	NA	*Pilea pumila*	Clearweed	Urticaceae	129	IMP
4022	111	*Robinia pseudo-acacia*	Black Locust	Fabaceae	477	IMP
4023	112-1	*Asclepias syriaca*	Common Milkweed	Asclepiadaceae	628	IMP
4024	112-2	*Solidago canadensis*	Canada Goldenrod	Asteraceae	1003	IMP

TABLE A.1 (Cont.)

CI#[a]	SI#[b]	Latin Name	Common Name	Family	MBBS[c]	Area[d]
4025	112-3	*Helianthus nutallii*	Giant Sunflower	Asteraceae	955	IMP
4026	113	*Juniperus virginiana*	Red Cedar	Cupressaceae	73	IMP
4027	114-1	*Solidago canadensis*	Canada Goldenrod	Asteraceae	1003	IMP
4028	114-2	*Robinia pseudo-acacia*	Black Locust	Fabaceae	477	IMP

[a] CI# — Collection number for voucher specimens.

[b] SI# — Sample number for chemical analyses.

[c] MBBS — Page number in McGregor et al. 1986.

[d] Area — Collection areas: PWL-Line 800 Pink Water Lagoon Area; IMP-Former Line 1 Impoundment Area; and EXD-Explosives Disposal Area.

[e] *E. muricata* and *E. crusgalli* are considered synonyms by some taxonomists.

[f] Synonym — *S. montevidensis.*

[g] Duplicate specimens of 4007.

Appendix B:

IAAP Analytical Results

TABLE B.1 Plant Uptake Study: IAAP Analytical Results (mg/kg)

Location #	Soil						Top				Root				Plant Sample
	TNT	RDX	TNB	24DNT	4A-DNT	2A-DNT	TNT	RDX	4A-DNT	2A-DNT	TNT	RDX	4A-DNT	2A-DNT	
1	48	<1	4.6	1.4	6.6	9.7	[a]								None
2	3,610	2.5	200	2.4	<0.5	<0.5	<0.5	51.2	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Smartweed
3	5.6	<1	<1	<1	<0.5	<0.5									None
4	42,700	5,010	510	17	<0.5	<0.5	<0.5	72.1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Bromegrass
5	526	59.7	6.8	<1	<0.5	<0.5	<0.5	3.6	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Pigweed
6	47.6	6.5	3.6	<1	3.8	5.5	<0.5	<1			<0.5	<1			Pigweed
7	6.3	<1	<1	<1	<0.5	<0.5									None
8	10,500	1,160	190	19	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	7.4	<0.5	<0.5	Arrowhead
9	9.9	1.4	<1	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5					Corn
10	4.2	<1	<1	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5					Corn
11	1.1	<1	<1	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5					Corn
12	4.5	19.4	<1	<1	<0.5	1.5	<0.5	10.1	<0.5	<0.5					Reed Canary Grass
13	1.6	<1	<1	<1	<0.5	1.3									None
14	<0.5	<1	<1	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	263	<0.5	<0.5	Goldenrod
15	<0.5	<1	<1	<1	<0.5	<0.5									None
16	0.6	<1	<1	<1	<0.5	<0.5									None
17	1.8	1.4	<1	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5			<0.5	<0.5	Reed Canary Grass
18	5.1	57.1	<1	<1	0.8	2.8	<0.5	35	<0.5	<0.5	<0.5	904	<0.5	<0.5	Goldenrod
19-1	0.9	9	<1	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5			<0.5	<0.5	Reed Canary Grass
19-2							<0.5	23.6	<0.5	<0.5			<0.5	<0.5	Goldenrod
20	13.8	114	1.6	<1	6.7	11	4.4	38.6	<0.5	<0.5	<0.5[b]	<1	<0.5	<0.5	Black Locust
21	15,900	702	99	<1	<0.5	<0.5	<0.5	73.9	10.7	4.5	<0.5	31.5	33.1	19.8	Ragweed
22	43	174	17	<1	<0.5	<0.5									None
101	26.5	<1	<1				<0.5	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Corn
							<0.5	<1	<0.5	<0.5					Corn Grain
102	5.5	<1	<1				<0.5	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Corn
							<0.5	<1	<0.5	<0.5					Corn Grain
103	2.3	<1	<1				<0.5	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Corn
							<0.5	<1	<0.5	<0.5					Corn Grain
104	32.2	3.2	1.2				<0.5	5.03	<0.5	<0.5	<0.5	4.09	<0.5	<0.5	Smartweed
105	11,000	1,800	183				0.76	41.5	<0.5	<0.5	<0.5	15.8	10	9.3	Bromegrass
106	22.6	3.8	1.3				<0.5	10.7	<0.5	<0.5	<0.5	20.2	2.8	12	Pigweed
107	143	3.7	8.4				<0.5	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Ragweed
108	4,660	166	8.1				<0.5	33.4	<0.5	<0.5	<0.5	17.7	18.1	14.8	Ragweed
109	33,700	1,100	21				<0.5	37.9	<0.5	<0.5	<0.5	2.3	290	4.4	Goldenrod
110	15.9	43.3	3.6				<0.5	<1	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Reed Canary Grass

TABLE B.1 (Cont.)

Location #	Soil						Top				Root				Plant Sample
	TNT	RDX	TNB	24DNT	4A-DNT	2A-DNT	TNT	RDX	4A-DNT	2A-DNT	TNT	RDX	4A-DNT	2A-DNT	
111	7.6	16	<1				<0.5	17.2	<0.5	<0.5	<0.5[b]	5.77			Black Locust
112-1	2.7	46.1	<1				<0.5	88.6	<0.5	<0.5	<0.5	8.2	<0.5	<0.5	Milkweed
112-2							<0.5	5.64	<0.5	<0.5	<0.5	<1	<0.5	<0.5	Goldenrod
112-3							<0.5	8.61	<0.5	<0.5	<0.5	4.28	<0.5	<0.5	Sunflower
113	4.7	16.8	<1				<0.5	42	<0.5	<0.5					Red Cedar
114-1	0.8	<1	<1				<0.5	<1	<0.5	<0.5					Goldenrod
114-2							<0.5	<1	<0.5	<0.5					Black Locust

[a] Blank = not tested.

[b] Black locust root = wood.